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These are tenants not guinea pigs: Barriers and facilitators of retrofit in Wales, United Kingdom

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ABSTRACT

Retrofitting existing homes with new energy efficient technologies is essential to reduce emissions and move towards achieving a 'net zero' carbon emission target. This paper reports on research that investigated the process of retrofitting new technologies in existing social rented homes in Wales, United Kingdom. It used mixed-methods consisting of pre- and post-retrofit surveys, qualitative interviews with tenants, and a documentary analysis of retrofit tenant engagement materials. Interviews and focus groups were also undertaken with a variety of professionals involved in the delivery of the new technology, including tenant liaison officers, architects, surveyors, and a civil servant.

Findings reveal that many of the barriers to deploying new technologies in social rented properties were around communication and information issues. The interface between the technology and residents was a challenge as mechanisms of the new technologies operation and sensors and monitoring were not understood well and residents were kept out of the loop often through digital exclusion. Disruption to norms, the home and everyday practices were also key barriers. Facilitators to successful deployment of new technologies included good tenant engagement, demonstrating and showcasing the technology prior to deployment and actively reducing disruption to norms and practices.

Social Practices Theory and Energies Culture Framework describe the findings well, especially around changes in material culture (the actual technology and hardware) and disruption to norms and social practices, which explains how the use of the technology by the residents notably changes and can disrupt their lives. These disruptions create anxiety creating further barriers which can lead to resistance to engaging with the technology. Better communication and more resident involvement and engagement are needed, allowing people ownership and some perceived control over the decision-making, deployment and changes happening to their everyday lives.

Findings suggest that communications and trust in the retrofit process are crucial to the success of delivering low-carbon technologies to tenants in social housing. The technology must also be usable and understood by the tenants; exemplar demonstrator properties to help tenants see and understand the technologies are helpful to successful deployment. In conclusion, more involvement of tenants is needed when delivering low-carbon technologies to their homes to resolve further exacerbating the already noticeable inequalities.

1. Introduction

With energy use in homes in the United Kingdom (UK) accounting for 14 % of carbon emissions [1], retrofitting existing homes with energy efficient new technology is a critical step to achieving net zero, where the amount of carbon dioxide created is no more than the amount that is taken away [2]. However, it is noted that the UK and devolved governments' net-zero targets will not be met without a 'near complete' decarbonisation of homes [1].

To achieve these targets by 2050, 29 million homes across the United Kingdom will require extensive retrofitting [1]. Indeed, it is estimated that, on average, about 12,000 homes per week will need to be retrofitted with energy-saving and low-carbon technologies in the next few decades to meet the 80 % emissions target [3]. However, retrofitting can be expensive and time-consuming, and currently, more skilled labour is needed to manage this or specific retrofit solutions when preserving

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heritage homes [4]. Consequently, encouraging homeowners and private landlords to retrofit their properties is perceived to be challenging [5]. Indeed, recent research with homeowners in Perth, Scotland, found that despite concerns about rising energy costs and climate change, current decarbonisation options were considered unaffordable [6].

Wales and the UK Government have thus focused on retrofitting at scale within social housing and have identified social landlords and their tenants as testbeds for low-carbon technologies and a vehicle for developing a broader retrofit market sector [7].

2. Literature review

2.1. Energy transition models and frameworks

The literature around energy, homes, and retrofit is extensive; consequently, this review sets the context for this paper and focuses on specific issues related to energy transitions and the human factors that may impact them, particularly regarding social housing. Strategies to mitigate climate change based on technology and fuel substitutions are described as socio-technical transformations, specifically here - energy transitions [8]. Criticism of 'top–down', "technocentric transitions" has highlighted the co-evolving nature of society and technology and thus the political and social dimensions inherent in the process [9]. Individual actors' behaviours, values and strategies shape energy system transitions as much as policies, regulations and markets [10]. Behaviours are not always rational nor easy to predict, hence a greater understanding of human behaviour and a more complex socio-technical systems approach is required. Understanding how socio-technical energy transitions might succeed is a major interdisciplinary research challenge. Many energy transition models do not fully account for the implementation of interventions at the household level [11], particularly concerning social housing. There is an absence of people-centred empirical research focussed on the well-being dimension at the household-level interventions [8]. This research takes into consideration both human and non-human aspects at play and how they interact in the domestic space to produce specific transition outcomes. In particular, it reflects on the Energy Cultures Framework [12,13], which provides the lens to explore the 'energy culture' within this particular setting and can reveal the interplay between material culture, norms and practices that may be understood differently by tenants, social landlords and Welsh Government.

Theoretical models include the energy ladder (a linear move to more efficient and cleaner fuels as individuals' economic status improves) [14] and energy stacking model (where new fuels and technologies are adopted alongside existing fuels to guard against unreliable supplies/prices) through to socio-technical energy transition, social practice and energy cultures perspective. The former models are less applicable within a UK social housing context, whereas although renewable energy and/or multiple fuels preservation may be desired by tenants, energy decisions are largely outside their control and driven by housing providers (and local/national government agendas). Indeed, Li and colleagues describe detailed requirements of energy transitions, including fundamental changes within social and technical systems and the involvement of multiple actors [10]. Similarly, Hirt et al.'s [15] proposal following their systematically reviewed energy and climate papers linked models and socio-technical transition theories to capture the co-evolution of society, technology and economy. They proposed that interdisciplinary learning and integrative research should be refocused to develop practical outcomes to meet energy and climate targets. The pragmatic idea is to think of a transition as a way of life, or in other words to enact the transition by integrating various stakeholders, citizens and experts to co-design transition storylines and conceptual models. Sociotechnical models are thus predicated on the understanding that multiple, intersecting technical, social, political and organisational systems are at play [16,17].

Social practice theory (SPT) widens the lens of analysis from individuals (within systems) to practices and focuses on the energy practices of everyday life; cooking, heating, cleaning etc. and the artefacts (technologies), competencies (involved in their use) and meanings (symbols) involved [18,19].

The Energy Cultures Framework (ECF) appears to be a useful heuristic to structure our analysis as it incorporates aspects of the other models, including technical, economic, environmental, social and cultural dimensions heavily focussed on human responses through structures of meaning in everyday energy practices. The ECF is especially useful in identifying how cultural constructions influence sustainable outcomes [21] and of relevance to this research, the ECF is effective in framing interdisciplinary research in housing retrofitting [23]. Stephenson [21] argues that low-carbon transitions are fundamentally societal transitions and thus include technical, economic, environmental, social and cultural dimensions and a greater understanding of human responses and actions can be obtained through symbolic and cognitive structures of meaning.

2.2. Opportunities and tensions

The rationale for targeting social housing as a retrofit testbed is twofold. Firstly, it offers an opportunity to improve the energy efficiency of social housing stock, which often falls short of low-carbon future requirements. Secondly, it is argued that such measures reduce energy costs for tenants and thereby address fuel poverty among groups most likely to suffer it [24]. However, critics of schemes aimed at reducing energy costs for those in fuel poverty argue that there are inherent tensions in such an approach because households in fuel poverty tend to under-consume rather than overconsume energy, meaning energy savings targets are not met [25].

Furthermore, it is argued that one of the most significant barriers to optimising the benefits of low-carbon technologies is the occupants themselves [26,27] as residents may be unable to manage their home energy use effectively or because new energy systems require different approaches [27]. In contrast, others argue it is a result of ingrained energy practices [26]. Whatever the reason, existing research shows that energy use can vary up to fourteen times between households, even in the same type of low-carbon homes [28]. This raises the question of whether residents are adequately prepared and have sufficient information to manage energy use and the new energy systems installed effectively.

To date, retrofitting of UK social housing stock with low-carbon technologies has been technologically driven and often implemented from the top down [29]. This approach can have implications for tenants, presenting challenges in understanding and interacting with the new low-carbon technologies installed in their homes [30] and also expectations around behavioural changes to achieve thermal comfort and their wider energy needs. Indeed, Brown et al. [27] argue that there is a degree of apathy or resistance from residents to changing the way they use their homes. Conversely Jansson-Boyd and colleagues [31], found that residents' identified barriers around lack of knowledge, and a lack of agency that their individual actions would make a difference [31]. For this reason, it is suggested that tenants should be involved throughout the retrofit process. This was reflected in guidance issued by the UK's Technology Strategy Board in 2014 [32], which recommended that people be placed at the heart of the retrofit process because involving residents or tenants at each stage helps manage expectations and avoids misunderstandings [32]. This is important, particularly as previous research has indicated issues around trust between landlords and tenants when instigating new home modifications, particularly where extensive adaptations and or new technologies are involved. This can manifest in negative or positive community-level stories shared by residents [27]. For this reason, Brown and colleagues recommend looking into how "occupants can be engaged in order to work towards a more successful programme of retrofit" [27,p. 650].

Involving tenants in the retrofit process is important from a

technological perspective because it is people who operate the technology post-retrofit, and challenges operating and engaging with new technologies can negatively impact the operational efficiency of the technology. For some groups of residents, such as older adults, technology can present additional challenges resulting from unfamiliar interfaces, different modes of operation of heating systems, and how these programmes are accessed, all of which can compromise the efficiency of the low-carbon measures installed [30]. The resulting performance gap is often rooted in social norms of thermal comfort, domestic routines and existing practices, competencies, and the ability (and desire) to master skills to manage new devices [33]. Older people also use energy differently in their homes. They are less likely to have modern energy-efficient appliances or replace old, less efficient technology with more efficient technology due to habits and memories associated with it [34]. They are likelier to live in older properties with little existing retrofitting of energy-efficient technology [35]. They spend more time at home, requiring extended heating periods and often use more gas in cold countries [36] or cooling in warm climate countries [35]. Thus, supporting consideration of Stephenson's ECF [21].

Furthermore, there is a risk of exacerbating or creating new problems for tenants, particularly those in digital poverty or those who are digitally excluded [37]. Indeed, digital poverty has been identified as a significant barrier to energy efficiency [38].

While much is known about the socio-technical aspects of retrofitting existing homes with low-carbon technologies, few studies have examined the process from the perspective of both tenants and social landlords. This paper addresses this gap by examining barriers and facilitators to a successful low-carbon retrofit from the perspective of social housing tenants and other actors involved in the Welsh Government's Optimised Retrofit Programme (ORP).

2.3. Welsh government optimised retrofit programme

The Welsh Government Optimised Retrofit Programme (ORP) was established in 2020 and formed part of its more extensive Innovative Housing Programme. Via funding of over £70 million, the programme's first phase aimed to support installing energy efficiency measures in over 1000 existing homes owned by registered social landlords and councils throughout Wales in a competitive application process The Scheme commenced in August 2020, with applications due by the 13th of September, successful applicants notified by the 12 October 2020 and an 'on site' start date no later than the 8th of January 2021. It was expected that retrofit work would be completed or money committed by the end of March 2021.

Five schemes secured funding in phase one, with one scheme being a consortium involving 27 social housing providers across Wales.

Phase one of the Welsh Government ORP programme adopted a test and learn approach to identify good practices in optimising the benefits across the whole process from procurement and surveying to installation. A combination of building fabric improvements and low and zero-carbon technologies (such as solar panels, battery storage and heat pumps), and intelligent ongoing systems (IES) to support optimum use of technologies were involved. Each property was individually surveyed to identify the adaptations needed for each home to achieve a low carbon footprint -route to net zero. All the homes were rental properties.

3. Methodology

3.1. Design

This research was a pilot mixed-method study using pre- and post-retrofit surveys, qualitative interviews with tenants, and a documentary analysis of retrofit tenant engagement materials. Interviews and focus groups were also undertaken with professionals involved in the ORP. This paper presents the findings from the qualitative interviews with tenants and the focus group interviews with professionals.

3.2. Case study approach and methods

Four case sites were included in the research, and all the homes were social housing (see Table 1). Twelve hundred homes were part of the phase one scheme, the number of homes in each case site varied. Delays to the ORP resulted in only four sites participating in the research. Three case sites retrofitted occupied homes, while one worked on empty properties. The works were undertaken between December 2020–July 2021. The data for this study was intended to be collected pre-retrofit and 6–12 months after the retrofit was completed; however, delays due to covid and supply chain issues compressed these timelines, resulting in tenant interviews being carried out shortly after the system was activated within their homes. Similarly, the focus groups with representatives from the social landlords and interviews with other housing professionals were conducted during the installation phase of the project on some sites and post-retrofit with others.

3.3. Recruitment and participants

Information about the study was distributed to tenants via the tenant liaison officers (TLO) at each site. Tenants could sign up for the retrofit programme without participating in the research. All tenants who agreed to the retrofit received information about the study and a resident interest form, which they returned to the research team via a prepaid return slip. In total, thirty-six resident interest forms (RIF) were received; however, several of these were completed on behalf of residents by the tenant liaison officers, who stated they had helped complete the RIF on behalf of tenants. However, when the research team followed up with tenants, several stated they had not agreed to participate in the research. Additional challenges to recruitment were posed by Covid restrictions within the university which altered the mail system, difficulties with Freepost set-up, and postal strikes in the latter stages of the project. This was reflected in the lower-than-anticipated take-up of the study. Follow-up telephone calls were made to all households who returned resident information forms. Of the individuals receiving a RIF, fourteen tenants agreed to be interviewed. Of the remainder, fifteen did not respond to repeated phone calls and messages; four refused outright, three cited lack of interest and one on health grounds. The list of tenant participants is included in Table 2 below.

In addition, to interviewing tenants undergoing the retrofit programme, two individual interviews and three focus groups were conducted with professionals involved in implementing the Optimised retrofit programme. These included tenant liaison officers, architects, surveyors, and one civil servant. All interviews and focus groups were conducted remotely using the Zoom video conferencing platform or Microsoft Teams. The semi-structured interviews with tenants were conducted via telephone.

3.4. Ethics and anonymity

Ethical approval was granted from the College of Human and Health

Table 1
Case sites and technologies fitted.

Case Site	ORP technologies and fabric improvements
Site A	Fabric improvements, PhotoVoltaic (PV) battery storage, Hybrid system Air source heat pump (ASHP), electric heating, IES = Passivsystem, Data monitoring
Site B	External Major Repairs + ORP: Fabric improvements, Glazing, Insulation, PV, Battery and water tank, IES system and data monitoring
Site C	Hybrid Retrofit: Hybrid System ASHP, electric heating; IES, Passivsystem, data monitoring
Site D	Empty/Void Retrofit Programme Fabric improvements, Triple glazing, Electric heating, ASHP, mechanical ventilation heat recovery (MVHR), Energy generation TBC, IES -Tyrell Products SmartDB-36, data monitoring

Table 2
Summary of sample and technology fitted.

ID	Household composition	Retrofit start and completion
Site A A2000	Couple age range 75–79	Work started 03/20 Completed Oct 2021
A2001	Couple age range 60–64	Work started 08/01/2021 Completed in July 2021
A2002	Couple age range 65–69	No information provided
A2004	On own age range 45–49	Work started Jan 2021 Covid stopped work- all working August 2021
Site B 1000	On own age range 55–59	No information provided
B1006	Lives with children age range 75–79	
B1008	Lives with partner and children age range < 50	Work started end of Jan 2021
B1011	Lives with partner and children age range < 44	Work started 3/2021 Completed 10/2021
B1012	Lives with children age range < 50–54	Work started 2/21 Completed June/July 2021.
B1013	Lives with spouse and children Age range 60–64	Work started 2/2/2021 Completed 15/5/21
B1015	Lives on own Age range 55–59	Work started 2/2021 Completed 09/21
Site C C3001	Lives on own Age range 70–74	No information provided
C3002	Lives on own Age range 60–64	Work started (Heat pump installed) 1st week Nov Completed11/11/21
C3003	Lives with partner and child Age range < 44	Work started Sept Completed October
C3005	Lives with partner and adult child Age range 65–69	Work started 4/10/21 Completed 14/10/21
C3006	Couple Age range 70–74	No start date given 12/11/21 heat pump turned on
C3007	Couple Age range 60–64	
C3008	on own Age range 65–69	Work started 8/2021, Completed mid-Nov 2021

Sciences Research to support this ORP research (12050d) and to include housing professional interviews (19102a) as an amendment to research planned and conducted as part of the Active Building Centre Research Programme research in new build homes (181219b).

3.5. Data analysis

The interviews and focus groups were professionally transcribed to enable rigorous analysis and the extraction of verbatim quotes. All transcripts and additional post-interview notes were uploaded into QSR NVivo 12 to form the data set for research. The data were analysed using a framework approach [39], with each researcher responsible for analysing either tenant or professional interviews. The framework approach uses a comparative form of thematic analysis within a structure (framework) of inductively and deductively derived themes, enabling researchers to move from descriptive accounts through abstraction to conceptual explanations. The method is transparent and enables teams of researchers to work together [40]. The analytic process began by identifying themes. These themes were inductive and resulted from an initial reading of the transcripts. They represented reoccurring themes across transcripts. The data were synthesised and refined within the framework. To increase the robustness of the process, regular discussions were held to discuss the coding, analysis, and interpretation of the data. The findings were drawn together over several meetings exploring similarities and differences in relation to the key research questions.

Themes centred around barriers and facilitators to retrofit from the perspective of tenants and social housing professionals working on the ORP. This paper presents the findings from post-retrofit interviews with tenants and interviews/focus group interviews with professionals.

4. Findings

The findings are explored from the perspective of social housing tenants and professionals representing the social landlords participating in the Optimised Retrofit scheme. The interviews were conducted post-retrofit but included questions that followed the process from pre-installation through retrofit installation to post-installation use by tenants. The paper will discuss how critical aspects of the process can act as barriers or drivers to retrofit.

4.1. Barriers

Barriers were often framed by the participants as communication and information issues, especially around building up an understanding of what was happening to people's homes, how they would be changed and norms and practices changed, and why such changes were needed. Similarly, changes in how the technology, through monitors and sensors communicate with and between the residents themselves was a key issue. How people were kept out of the loop through exclusion, especially digital exclusion, where people needed to understand and be able to use the technology is a further barrier. Finally, disruption to norms, the home and everyday life was also a key barrier.

4.1.1. Communication and information

The main barriers tenants and frontline social housing professionals identified were the need for more information and better communication. This included not only information given to the tenants but also poor communication between and within organisations involved in the programme.

For professionals, the need for more information about the systems and technology being installed in the homes immediately impacted their ability to encourage tenants to agree to the installation.

> But personally, I didn't feel comfortable encouraging them to go for something that new because I didn't know enough about the system myself, there wasn't evidence of it *actually working.*
>
> (Professional PRF007)

It also inhibited tenant-facing staff from including some households, which would potentially benefit from low-carbon technologies, from being included in the retrofit programme for fear of making already precarious financial circumstances worse, as illustrated below.

> Some tenants that haven't got any carpets, you know they haven't, they can't afford what they're paying at the moment, … And you're there, you're trying to do a job, but sometimes you feel, am I confident in selling this to them? And sometimes, I don't believe in the product because I don't want to put these in poverty.
>
> (Professional PRF0004)

Although there was no financial cost to the tenants for the retrofit, some TLOs were uncertain whether the installation would increase energy costs if used incorrectly, resulting in a reluctance to encourage tenants to participate in the programme for fear of worsening fuel poverty. Likewise, while a small minority of tenants felt they had been well informed, others highlighted various communication issues even on the same case site. This reflects the differing information needs of tenants.

> If that's one complaint I had to have, would be communication was poor. … We've had to wing it between us
>
> (Tenant B1013)

Despite all the professionals interviewed expressing a commitment to tenant engagement, they felt that the timeframes of the ORP did not allow for adequately allow for this before work began. Processes of informing tenants of the work plans differed between social landlords, with some sending a standard letter stating they were undertaking maintenance works.

> All we got was a letter was saying I think it was in September saying, "You're having a new roof." So that's all we thought we was having was a new roof. We didn't know we was having solar panels. We didn't know we was having stuff done on the property, like the insulation.
>
> (Tenant B1008)

While other tenants were given information verbally

> Int: So you didn't really have anything written down?
>
> Res: No, no. Just words of mouth […] A couple of people said, "Oh, we're getting houses done."
>
> (Tenant A2004)

In contrast, tenants on other sites received glossy written marketing information. However, tenants and frontline housing professionals noted that this was often not tailored to a 'non-expert' audience and overlooked the low literacy levels among social housing tenants, as noted below by one professional.

> You have to understand that in areas of deprivation within social housing, probably as a rule, there are going to be a high level of probably literacy issues, and there's lots of people that – materials and not being produced in – well, we haven't produced them anyway, in other languages at the moment. [marketing company] haven't provided them in Welsh even. So, you've got lots of issues where people don't necessarily have technical knowledge, and then also, you throw in words to them 'optimised retrofit' (Professional PRF0002).

This resulted in some professionals reworking and condensing the information to make it accessible.

> The pack from [Marketing company] from the project is helpful to me as a person professionally, so I understand what it is that we have to do […] I didn't use any material with the tenants[…].
>
> (Professional PR0001)

Of more significant concern was the admittance by some social landlord staff that, in the case of older householders, the amount of information given was deliberately limited and was related to concerns that older tenants would refuse to have the works done if they knew what was involved.

> So, with the over 60, I've been very, very limited on the information that I'm giving. I'm just giving the bigger picture, saying we have things that we have to do.
>
> (Professional PRF001)

Even when information was provided, it was not always as detailed or accurate as tenants would have liked.

> RES: I had a phone call saying the council are trialling these new air source pumps. Would I be interested? I said, yes, carry on. They came out, they did a survey, and they said, "It'll be this big, it won't be intrusive, it's quiet as a mouse." And I'm, "Yes, go for it, do what you want." This thing is a monster – it is huge. It is noisy. […]
>
> (Tenant C3003)

It may be that professionals disseminating information to tenants were also not fully cognizant of all the details regarding the installed technologies. This was a cause for concern among professionals who noted that *"bad news enjoys travelling faster than good news",* with concerns about the impact negative feedback would have on tenant relationships and customer satisfaction.

> What I'm more worried about is it's going to affect our customer satisfaction ratings now; we sort of – some people have been having a go, and I've said our customer service ratings are down,
>
> (Professional PRF002)

There was also concern that tenants discussing issues among themselves may have potential implications for the wider retrofit programme when problems arose.

Poor communication and a lack of information were potential barriers post-retrofit, with tenants expressing a need for ongoing information on general queries and achieving optimal usage of the technologies.

Post retrofit, there was often limited access to information in the format they wanted, with tenants wanting information in an accessible and timely manner. In some instances, information on the optimal use of technologies did not appear to have been provided. This resulted in tenants being unable to achieve thermal comfort or the energy use they desired at an acceptable cost. In some cases, this resulted in tenants switching off their systems, as noted by one tenant at case site A who had switched *"hybrid [system] off completely at source outside."* The same tenant also spoke about a neighbour stating, *"She reckons she's turned it back to having just gas like we were before"* (Tenant A2000).

This was echoed in other sites, as illustrated below.

> "[turned off] a battery pack thing, as I say, it's never worked. So, I turned it off because it was using, for some reason, it's been using up our electric."
>
> (Tenant B1011)

While a lack of information meant others were not using the systems optimally, for example, by working from thermostats as opposed to Apps "*because they're going to use the thermostat, and then the machine's going to be working harder, so it's going to use more electricity"* (Professional PRF004).

Furthermore, some tenants had 'taught themselves' using YouTube videos and peer learning. While this may be useful in the short term, it is potentially problematic as it could lead to learning about systems that do not operate in an identical way to the one installed or passing on incorrect advice within that community.

4.1.2. The use of monitoring and sensors

Another critical communication issue was the use of intelligent monitoring systems (IES) and sensors.

The professionals interviewed were often unclear about what was being monitored and for how long.

> We're going to have this monitoring system coming to their home, which is only going to operate for 12 months; anything beyond that, we don't know…
>
> (Professional PRF0001)

There were also concerns around the IES, data sharing, and GDPR, with one professional stating, *'It just feels like we're heading down something that's just going to be a car crash'*.

This same professional was concerned that there would be pushback from tenants regarding data sharing.

> One of the things that we know is a strong value for tenants is data protection, just from other projects that we work on. I can see a lot really challenging the data sharing around the information and I think that it's something that they, a lot of people, the general public, probably feel quite strongly about.
>
> (Professional PRF0006)

While some professionals viewed monitoring as '*ammunition'* to counter claims of dampness within the home.

> At the moment, I'm not sure where it does fit in…we're collecting the data, one thing that would come in handy on our side is, because most of our claims, insurance claims is through damp, and that's just because of a lack of heating. But with these monitors, I think it's like ammunition for us to go back to say, "No, you're not using your heating".
>
> (Professional PRF004)

In contrast, some tenants saw advantages to the monitoring equipment, particularly in being able to detect problems and correct or repair them remotely,

> RES: About a week ago, at my house, sorting out the battery pack under the stairs. Apparently, something had gone off. Somehow it had got switched off. I don't know how that had happened.
>
> INT: And how did they know that?
>
> RES: They've got sensors.
>
> (Tenant B1015)

Sensors were also a contentious issue due to a lack of information as to their purpose and how people started to infer meaning on them,

> And we have boxes in the living room in the ceiling, and we have a box in the ceiling in the boys' bedroom. But again, I didn't want them because it looks stupid, but they didn't tell us what they were for. […] our middle one (child) is autistic. […] he keeps saying, "We're being watched."
>
> (Tenant B 1008)

and, to the siting of the sensors, particularly in bedrooms where the brightness of the LED lights on the sensors was an issue.

> …all these sensors on everywhere flickering. They've got little blue lights, so it's not dark anymore when you go to bed. There's one in the bedroom and that's quite bright.
>
> (Tenant B1015)

Issues of data sharing and uncertainty about what information was being shared and with whom represent a potential barrier to retrofit for tenants. Uncertainty and lack of information on the need for monitoring, their positioning and appearance, alongside issues of illumination in bedrooms from sensors, will undoubtedly concern some tenants. It was evident that both professionals and tenants required information on the sensors and data sharing.

4.1.3. Digital exclusion and retrofit

It was evident from both the tenant narratives and those of tenant facing professionals that digital exclusion was a significant problem that prevented some households from taking up the retrofit offer.

> We've just had one or two of them point blank refusing, now wanting to take part in the programme because they have to have Wi-Fi, or they have to have the digital device to obviously work the heating system.
>
> (Professional PRF007)

Digital exclusion also meant that some RSLs were ruling out older householders because of a lack of Wi-Fi connectivity, potentially widening existing inequalities.

> They need to have internet connection, yes. So, that rules out most of the elderly [people]properties that we had because they don't need it. They need to have access to a smartphone.
>
> (Professional PRF0011)

In the case of older adults, some RSLs were overcoming the problem of digital exclusion by bypassing the older adult and giving a family member control of the app and the technology/heating.

> The smartphone thing, I think is more, like if you've got an elderly lady and it's ideal for her, this system, then a family member can have the smartphone, you know, with the info on, and we've gone down that route.?
>
> (Professional PRF0012)

Such a paternalistic approach removes agency from the older adult and impacts their ability to maintain their independence. With a rapidly ageing population residing in social housing, more consideration needs to be given to who will use the technology and how it will be used. If there is no option but to go down the digital route, then digital skills training should be offered to those wishing to have the technology but who need more skills to utilise it effectively.

Yet, there were concerns even among tenants who were open to digital technology. Some tenants were unsure how to operate their new system from the app or were uncertain how to alter settings as and when needed. Furthermore, several tenants had to have the app installed and heating settings programmed for them by members of the ORP team, while others were not comfortable having an app installed on their phones or tablets.

The future cost of connectivity was also identified as a potential barrier, as Wi-Fi access was a requirement for the retrofit systems to work. In the ORP scheme, Wi-Fi access was being paid for by some RSLs; however, concerns were expressed about the long-term cost implications for RSLs in continuing to provide free Wi-Fi to tenants. However, passing the cost onto the tenant poses an additional barrier regarding affordability.

4.1.4. The disruptiveness of the process

Retrofit works are by nature disruptive, and this was a significant barrier, particularly for older tenants, as noted by professionals who felt it was a hard sell to tenants.

> The tough sell with tenants and take up is going to be when we're offering what is essentially quite intrusive works, and for very, or what might appear to be in limited payback for the tenant. Because they may appreciate that it's a process of decarbonisation over a number of years, but if you're an elderly resident living somewhere, you know, you probably don't want to hear that we want to inconvenience you quite a lot.
>
> (Professional PRF002)

Tenants themselves reported being shocked by the level of disruption, indicating that the process and scale of the work were inadequately communicated to them.

> I think I might have arranged to go away for a couple of weeks, actually.[…] it would be easier for them to have an empty house to work on, wouldn't it, and then for, you know, for us.
>
> (Tenant A2001)

> We didn't think it was going to be as intrusive as it was.[…] When the scaffolding went up it was a bit of a shock to the system because it was like the whole house was plunged into darkness, and the amount of people that were here and things like that, on a daily basis. In the height of it, it was quite overwhelming,
>
> (Tenant B1013)

This same tenant felt that they would have been better prepared for the disruption if they had been given more information.

> I just wish we'd have known a bit more, and like you say, we could have done a bit more preparation on our side of things.
>
> (Tenant B1013)

There were also some concerns from professionals around damage to people's homes resulting from the works.

> quite a few of them (homes), are very well decorated, nice carpets, they have been there a long time, and they have really made it their home, you feel then that you look and think this was wallpapered maybe five or ten years ago. Actually, the wallpaper is immaculate; we can't match that, you know. It's hard, you know, and you've got to try and think of the best way to do things because it's their home.
>
> (Professional PRF0003)

For some tenants, the work negatively impacted their relationship with their home and their well-being.

> I loved my house. My house is my safe place, nobody comes in my house. I give up caring anymore to be honest with you, and it's sort of like, well, if there's something wrong with it, it's not our property, it's their property. I'm not arsed anymore, and I took good pride in my property.
>
> (Tenant B1008)

Issues such as those highlighted above can prevent other tenants from engaging with the retrofit offer, especially as noted by one tenant, "*Everybody's moaning about it*" when talking about aspects of the retrofit.

This was also highlighted in the narratives of the professionals.

> If we do anything to a tenant's home and it turns out to go badly, or it's not what they expected, they'll be very quick to say to the next-door neighbour, "Don't have what they've done to my house, because it doesn't work," or, "It's cost me more money to run."
>
> (PRF008)

The disruption to properties appeared to be extensive in most of these case sites as the retrofit included necessary fabric improvements, including roof repairs, new windows, and the new technology installation. As pointed out by both landlords and tenants, it would have been preferable if the extent of the disruption to homes while the low-carbon technologies were installed had been more explicit. This was especially important given the context in which the work was undertaken during winter during a global pandemic. This can not only have influenced how the tenant felt about the process but also how they felt about their home. This has implications for their well-being and the long-term maintenance and upkeep of the property in the longer term, as expressed by one of the tenants above. Resident experiences and attitudes towards the retrofit process, both before and after the installation of measures, are central to achieving the success of a retrofit project.

4.2. Facilitators for successful retrofit

Facilitators to successful deployment of new technologies included good tenant engagement throughout the process, and also working on empty properties with potential to showcase and demonstrate technologies with minimal immediate disruption to norms and practices.

4.2.1. Tenant engagement

Early and ongoing tenant engagement was essential for a good outcome. One professional argued that more consideration needs to be given to the impact such changes have on tenants, both during the works and post-retrofit, regarding how they live in their home, noting, "*These aren't guinea pigs that are living here. These are people's homes.*"

Involving tenants early in the process was seen as a positive, as evidenced by one professional's experience with an earlier pilot project.

> Our tenants […] they've been involved again, every step of the way. They were involved in the modelling. They know me personally. […] So, every time we were learning something, we would go back to the tenants, sit down, maybe have a cup of tea and say, "Look, so this is what we are looking to do," and I'd show them a picture of what it would look like.[…] it is important that we keep them on board because this is a risky journey as well.
>
> (Professional PRF008)

The same professional described how they worked closely with one tenant undergoing retrofit. The tenant was temporarily rehoused while the work was completed on the empty property.

> So, she has been very much part of the journey, seeing how her home has gone from a dirty home, as she considers it, to a more green home using renewable technology such as solar panels, battery storage, ESOS heat pumps. So, it is giving her what she wants.
>
> (Professional PRF008)

The professionals working on this case site (starting with empty properties) described how they were engaging tenants on plans for future works retrofitting more of their housing stock.

> I'd done a couple of focus groups with different tenant groups, just a couple of presentations, explaining what we were looking to do in this particular street and just getting their views –It's quite pleasing to see their reaction and then also get challenged back, saying, "Oh, have you considered this? Have you considered that?"
>
> (Professional PRF008)

The importance of good communication and training for tenants is not to be underestimated. The process is a partnership between the RSL and the tenant; how the tenant engages with the technology will influence its effectiveness. Misusing it can lead to higher costs and ultimately have a negative impact on meeting the net zero targets.

> For the retrofit, though, we have always said that 50% of it is us installing the works. The other 50 per cent is how the tenants use them. Again, we can have the best will in the world. We can make the most energy-efficient, air-tight property that doesn't lose its heat and performs perfectly, but if you have a tenant that likes to wake up every morning and open all the windows, because they like the fresh air.
>
> (Professional PRF008)

4.2.2. Working on empty properties

Given the level of disruption and the unfamiliarity with the technologies being fitted, it was surprising that only one social landlord chose to undertake the installation on empty properties.

> We did like a demonstration house; it was only because it turned into a void house, and there was no one in there at the time. So, we had maintenance round there; I mean, the CEO was there as well, but they could see exactly what we'd put into these houses, and then, because there was a call centre guy there as well, they could see what it was physically, you know. And that knowledge will get transferred then to their teams.
>
> (Professional PRF005)

5. Discussion

Retrofitting existing homes with low-carbon technologies is necessary to achieve the net zero targets set by Governments. Nevertheless, the focus has been on the technological aspects of the retrofit and the home post-retrofit performance rather than the tenants' experience, as supported by Jansson-Boyd et al. [31]. As such less is known about the experiences of tenants and staff working for social landlords during the retrofit process. The findings illustrate the need to understand transitions through a more complex social-technical systems lens. Evident through the findings was that delivery of low-carbon technology results in a change of daily practice, a change in habit, norms and expectations commensurate with a social practice theory, and as a result competencies and meaning are altered for the residents [20]. In addition changes in practice and norms can be further noted as significant as they involve a change in material culture (in actual technology and hardware within the house), practices (actor's actions and activities) and norms (expectations and aspirations) and as such are well examined through a Energies Culture Framework [21]. In this study, we have evidence that develop these frameworks further, identifying for example that disruption to social practices, competencies, meaning, norms, and material culture causes anxiety, and resistance, but that this can be overcome with good quality communication, trust and understanding how social practices operate as a conduit for the power of such disruption. At the heart of this involves greater end-user, public or community involvement, to take people along with the decisions made, allowing decisions

to be made with, rather than made to the households.

Anxiety generated by change of practice, competency and meaning is somewhat placated with communication and information provision, but even that was not always enough.

Good communication is the cornerstone of a successful retrofit programme. The provision of accessible information in various formats, given at different time points throughout the process, helps tenants prepare for the works, manage any difficulties or issues during the process, and post-retrofit helps optimise their use of the technology. Tenants reporting a positive experience felt they were well-informed and were satisfied with the level of communication they received. This contrasted with those reporting a less than satisfactory experience, who felt they needed to be more informed and prepared for the disruption to their homes. This suggests the need for tailored information, provided in different modes, written, verbal and visual (videos). With information given at each stage of the process, pre- and post-retrofit. Communication is also important for professionals working on low-carbon retrofits. It was clear that communication within and between social landlord organisations was an issue, this in turn impacted the information that was given to tenants.

One crucial way to communicate the change, to reveal the changes to material, culture and practices needed, is to demonstrate how far this might happen without actually having to make the change immediately. Seeing others who have been through the process successfully, especially similar people or households may influence people to make a change. Second, using empty homes as demonstrator houses can also facilitate the process, offsetting many of the issues during the ORP within this study. In the first instance, good practice would appear as Case site D, where the entire process and technologies could be tested initially in unoccupied homes providing a 'safer' learning experience and the opportunity to observe and plan for any potential issues that may occur in occupied homes.

Communicating with people also has the advantages of increasing carbon literacy and understanding of climate change. The findings suggest that those who were more involved in the communication also welcomed additional information as to how they system works within wider systems and understanding of sustainability issues facilitating a change in culture, rather than just a change in individual system.

Central to the change in practice and norms for people, was an increase in technology use through digital interfaces often with associated App. While that may work well for younger users, there was noticeable resistance from older, less digitally engaged individuals who would then have the app controlled by a third party or family member. Since such an app is often central to the successful deployment of the system, lack of being able to use it in the manner designed meant the system felt somewhat out of the user's control. Taking an Energy Culture Framework perspective [12,21,22], the system either then needs a better more intuitive interface, designed around current practices, this could be as part of the existing material culture, for example the hardware like the boiler, thermostat etc. This is also the case when material culture changes, like there being no boiler or a change in how the technology looks, along with additional room sensors, and associated lights etc. Keeping material culture looking similar, or communicating how it differs from norms and expectations is a way of overcoming this.

What was very noticeable was that unintended consequences can arise from top-down decision-making choices and implementation mechanisms. Existing research has shown that fear of the technical aspects of the installation, alongside perceptions that the retrofit process itself is a hassle, potential changes to the aesthetics of the home because of the installation, and uncertainty around their future in the home can all negatively influence the decision-making process for tenants [41]. This is important as, unlike purchasers of newly built low-carbon homes, who make a conscious decision to transition to low-carbon technologies, social housing tenants are rarely involved in the decision-making process, whether this relates to decisions regarding the technologies installed or the siting of new technologies within the home as was also indicated by Chahal, Swan & Brown [42].

Trust also has a significant role in the retrofit process; this includes trust in the landlord and the tradespeople undertaking the installation. Brown et al. [27] argue that trust is central in retrofit discussions, being a critical barrier to adoption and efficient use transmitted through stories residents tell themselves and each other. This was a significant concern among social housing professionals in this study.

This makes it even more critical to engage tenants early in the process, to understand households and their everyday lives better, and to tailor retrofit programmes to the needs of different social groups [43]. Trust is critical to the success of retrofit programmes and is built through recommendations from family, friends, and neighbours [43]. Indeed, it has been argued that community-based approaches that draw on existing social networks and other trusted messengers may be beneficial in promoting retrofit programmes [44].

This highlights the importance of giving adequate time for tenant engagement before the process and throughout the retrofit process, and this was also found in previous research [27].

6. Conclusion

Having a role in the decision-making process should apply to all tenants regardless of age or circumstances. There was evidence that older adults and those in financially precarious circumstances were excluded from the programme or not consulted on installing the technologies. For some older adults, the decision to install the technologies and control the systems was devolved to non-resident family members. This was also observed in Lusambili's work [30] which found that older people who were digitally literate were better placed to make decisions about heating technology than those who could not access the internet.

The instant dismissal of these properties (and people) risks further exacerbating inequalities and inequities. While it is acknowledged that the decision to exclude some households or remove agency from others may have stemmed from the forced speed of the process, which allowed insufficient time to 'leave no one behind' and reach first those who are furthest behind as per the mantra of the Sustainable Development Goals of Leaving No One Behind [45], this needs to be factored into retrofit planning.

However, for older residents, this paternalistic approach may be seen as ageist as it removes agency. In that case, it is essential to understand people's concerns and offer digital skills training to those wishing to participate in retrofit but who feel they lack the skills to use the technology effectively.

The focus on technological aspects overlooks the values people place on their homes and how this may play into their energy decisions and behaviours. While this was understood by professionals, particularly the TLOs, it was not always recognised by other professional groups involved in the process. The lack of understanding of these values can lead to resistance to technology uptake, resulting in tensions between project aims and mutually appreciated outcomes. This provides a strong rationale for why tenants must be considered essential stakeholders in transitioning to low-carbon energy [37,46], in this case, via retrofit while living through the process. It is well established that public involvement (of intended beneficiaries) supports the implementation and development of new sustainability projects and that lack of stakeholder support can result in significant opposition [47]. Consequently, public engagement is integral to the success of such projects. This has to be balanced against the financial and time constraints of projects, but increases in costs short-term may save money long-term.

The findings have demonstrated that crucial barriers to successful retrofitting of low carbon technologies include those found in Social Practices Theory [20] and Energies Cultures Framework [21], especially around changes in material culture, such as the technology and hardware found within the house, disruption to norms and social practices, competencies and meaning, for example how the technology is used and operated by the resident's actions and activities and associated

expectations and aspirations for it. These disruptions create anxiety which can lead to resistance and is made worse through the top-down nature of deployment which can be overcome by a process of involvement and engagement with the end-user social practices. At the heart of successful implementation of low carbon technologies involves greater information and communication along with more end-user, public or community involvement, to take people along with the decisions made, allowing decisions to be made with, rather than made to the households, allowing people ownership and some perceived control over the decision-making, deployment and changes happening to their everyday lives.

6.1. Limitations

Finally, it is worth noting that the project was not without its limitations. Challenges posed by covid restricted face-to-face access with participants and meant the research team could not undertake engagement activities in each case site before data collection or directly recruit participants. It is also worth noting that during the recruitment period, residents were receiving information about the retrofit via TLOs – this meant that residents were presented with a lot of paperwork during what was a stressful time with work on their home being undertaken alongside the impact of covid.

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Data availability

The data that has been used is confidential.

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